Thermal Diffusivity Measurements Across Submicrometer Metal Thin Films by the Picosecond Thermoreflectance Method

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A new picosecond thermoreflectance measurement system using an electrical delay control has been developed in order to extend observable time region of heat diffusion inside thin films after pulse heating. The new system uses two picosecond titanium sapphire lasers, one for heating the specimen, and the other for probing the temperature change on the surface. The temperature history curve of the film surface is obtained by electronically changing the delay time of the probe pulse to the pump pulse, instead of changing the difference of path length between the heating beam and the probe beam. This measurement system is free from misalignment of the optical delay line, and has no limitation about the maximum observation time. The temperature history curves of tungsten thin films of 140 nm, 200 nm and 300 nm thickness are observed over 65 ns (five repetition periods of the picosecond lasers) for the first time. A new model is presented introducing a repetitive pulse heat source and a steady heat sink on the boundary between a film and a substrate. The thermal diffusivity of the tungsten thin film of 300 nm thickness calculated from the model is 39% of that of bulk tungsten. By using this system together with phase detection method, which improves quality of the thermoreflectance signal by observing phase components of lock-in output instead of amplitude components, the picosecond thermoreflectance method can be applied not only to metal thin films of thickness around 100 nm, but also to various thin films such as multilayered thin films or nonmetal thin films.